

Fallows
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or 5 or 10 million people and the devastation of the Midwest, and would grant the Soviet leaders whatever they had in mind. *Even if the attack never came*, Nitze and his friends suggest, a President fearing Minuteman vulnerability would know that it could come, and knowing that, would ever afterward lack spine.

This is an argument of vast political moment, but it turns on several purely technical points. One is accuracy—whether missiles fired at the Minuteman silos would be likely to hit. Through the last year, the news-

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The United States has never successfully fired a Minuteman from a normal, operational silo; after four unsuccessful attempts, the Air Force stopped trying.

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papers have been full of reports about newer, more "accurate" missiles on both sides—the Soviet SS-18, with a theoretical accuracy of better than one tenth of a mile, or our own proposed MX, with similar capabilities. These accuracies are important because of the targets involved. Nuclear explosions do much of their damage through shock waves, or "overpressure"; a 1.2-megaton bomb, the size carried on B-52 bombers, can (depending on the height of the explosion) create overpressure of 5 pounds per square inch—enough to crush a house—for nearly 5 miles in every direction. Missile silos are designed to endure overpressures of 1000 pounds per square inch or more. A nuclear explosion can create that kind of pressure; but only if it scores a virtual bull's-eye on the silo, falling within a few hundred yards (depending on the warhead size) after its flight of many thousands of miles. Published accuracy figures suggest that this can happen; the technical realities practically guarantee that it can't.

The usual technical measure of accuracy is "circular error probable," or CEP. If you fire off a dozen missiles and draw a circle in the middle of their impact pattern that contains half their impact points, the radius of that circle will be the CEP. What this tells you is the consistency of the weapons; if applied to a shotgun, it would measure how tight the pattern was. What it does not tell you, at least not in the form most often published, is how close the weapons came to what they were supposed to hit.

For that, another measure is required—"bias," a term certain to make nuclear analysts wince. Bias is the distance between the center of the impact pattern and the intended target; if you aim at Moscow and rain

death on a village 20 miles to the east, you have a bias of 20 miles. No one knows all the causes of bias, but some of them are gravitational quirks, unexpected winds, the varying densities of the air, anything that disrupts the calculated perfection of the ballistic path. It is a measure of reality, not theory, and *it is almost impossible to predict in advance*. "In almost every case where we've fired a missile over a new range," Richard Garwin says, "we've discovered a new element of bias. People make the adjustments and say they've got the bias under control, and then they try a different range and it starts all over again." The descent of Skylab is an extreme example (since it encountered bias over many orbits, while ballistic missiles don't fully orbit the earth even once), but the uncertainty about just where Skylab would fall illustrated the kinds of errors that can occur.

When missiles are fired at the same target over and over again, as they are from Vandenberg Air Force Base in California to Kwajalein in the South Pacific, and on Soviet ranges in Central Asia, the bias for that particular flight path can eventually be worked out by trial and error. The process is similar to a howitzer bracketing its target—the first round too long, the second too short, the third dead-on. But in a first-strike nuclear attack, there would be no chance to bracket; the first shot is all you would get. That shot would have to hit—even though there has never been a test flight over the path the Russian and American missiles would take, and thus the anomalies and bias that would certainly occur can in no way be predicted. On the test range, a missile with 300-yard "accuracy" can be counted on to come within 300 yards of its target about half the time. In combat, those missiles could be like a fine shotgun: its pattern tightly bunched, but not a single piece of shot hitting the bird.

Every weapons technologist I spoke with clearly distinguished theoretical "accuracies" of the missiles from likely performance. "Uncertainty about performance of these weapons has kept the peace for thirty years," one said. No one doubts, despite all the inaccuracies and foibles, that the United States and the Soviet Union, with 15,000 strategic nuclear warheads between them, could come close enough to destroy cities and annihilate people. But very few who understand the mechanics of nuclear weaponry consider the perfect timing, precise coordination, and pinpoint accuracy of the first-strike scenario as anything more than a frightening but unrealistic fantasy.

The technical journals are full of other reasons that prudent leaders might well pause before launching the theoretically possible first strike. Will the missiles get